

LATE ORDOVICIAN CRINOIDS FROM HAILES KNOB, UPPER TAKAKA, NEW ZEALAND

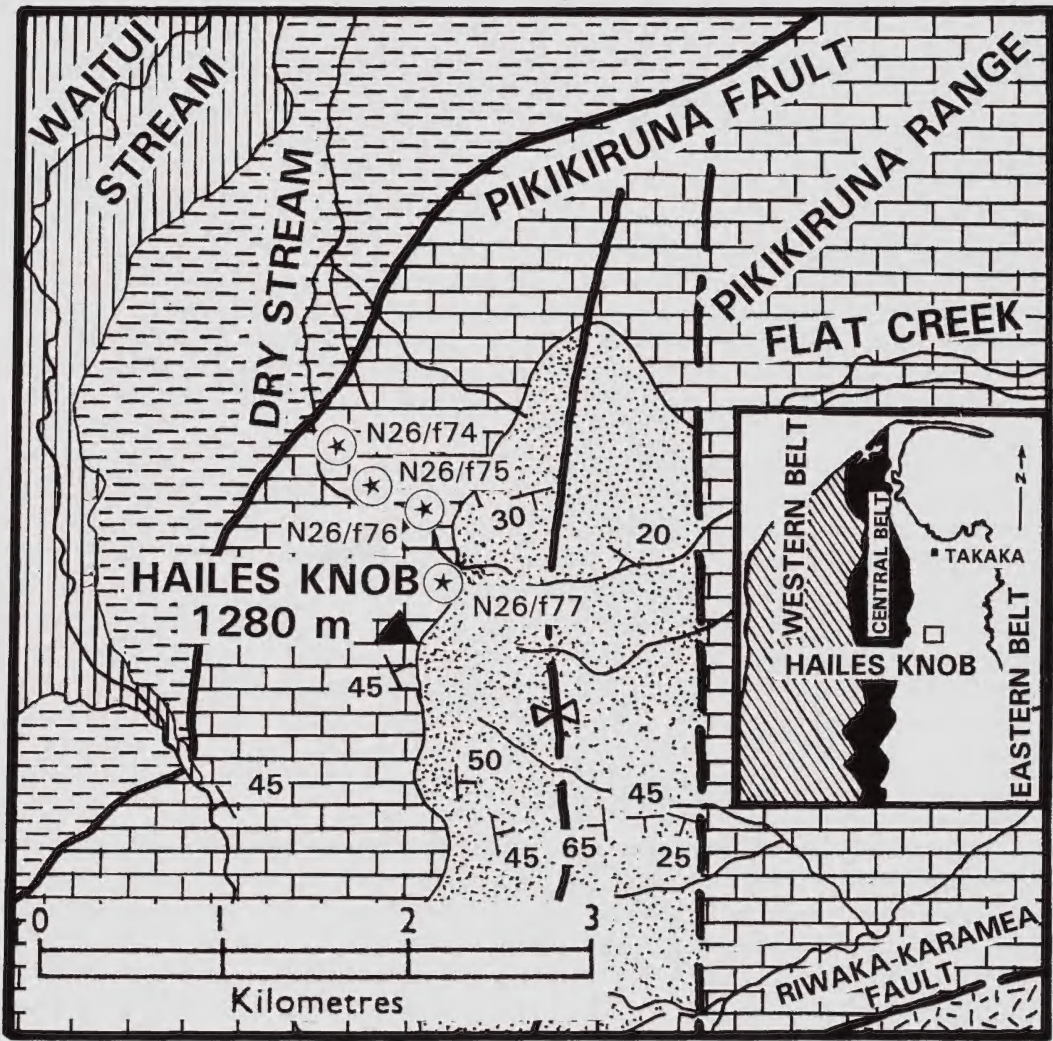
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Abstract. Late Ordovician crinoid faunas are described from the Arthur Marble of Hailes Knob, Upper Takaka, north-west Nelson. Three camerate crinoids and the first inadunate crinoid from New Zealand are recorded with the genera *Reteocrinus*, *Archaeocrinus*, *Deocrinus* and *Aetheocrinus* being recognised. They are the earliest crinoids to be described from this country and are interpreted here as having migrated from a North American mid-continental shelf environment.

The earliest pelmatozoans discovered in New Zealand are those of Early Ordovician (Arenigian) age found at Springs Junction, Mt Owen and Mt Arthur, South Island. They exist as recrystallised external and internal casts that have been structurally distorted beyond identification. Further Late Ordovician (Ashgillian) pelmatozoans are found in Arthur Marble at Hailes Knob, Upper Takaka, north-west Nelson. These are also internal and external stem columnal casts. The lack of recognisable thecae in this assemblage has previously deterred formal description, however, some recently collected columnals show sufficient morphological detail to enable them to be identified. This paper records for the first time columnal morphology of some of these earliest known fossil crinoids of New Zealand.

PREVIOUS WORK

McKay (1879, 1892), Cox (1881) and Park (1890) surveyed the older Palaeozoic rocks in the eastern part of north-west Nelson. Marshall (1912) and Benson (1921, 1923) refer to the chronostratigraphy of the area. Benson *et al.* (1936) reviewed the lower Palaeozoic fossils of north-west Nelson and Henderson *et al.* (1959) completed a regional map. H.W. Wellman discovered a fossiliferous, leached, calcareous grit "float" boulder containing brachiopods and crinoid ossicles in Dry Stream in 1960. This boulder was lodged at Victoria University (V972) and subsequently proved to be derived from the Hailes Knob Quartzite (Cooper & Wright 1972), overlying Arthur Marble. Grindley (1961) mapped the Arthur Marble found in the Upper Takaka area as Late Ordovician in age. Cooper (1965, 1968) recorded known fossil localities of the area. Wright (1968) recorded conodont taxa from a boulder from the western face of Hailes Knob and deduced an Ashgillian or Late Caradocian age for the "Arthur Marble" found there. Cooper & Wright (1972) recorded Lower Silurian Hailes Knob Quartzite and fossils from Hailes Knob, north-west Nelson, thereby filling an important gap between the Late Ordovician and Early Devonian faunal sequence in New Zealand. Cooper (1975) subsequently summarised sedimentary, igneous and tectonic early geological histories of the north-west part of the South Island of New Zealand.



-  Cenozoic (★) FOSSIL LOCALITY
-  Hailes Knob Quartzite (Silurian)
-  Quartz-sandstone, phyllite (Ordovician-Silurian)
-  Arthur Marble (Late Ordovician)
-  Igneous and metamorphic (Riwaka Complex)

Fig. 1. Locality map of north-west Nelson. Geographical sketch map showing the distribution of the eastern, central, and western depositional belts [after Cooper & Wright (1972) and Cooper (1975)], and the Late Ordovician crinoid fossil localities at Hailes Knob.

GEOLOGY

The Pīkikiruna Scarp containing numerous but isolated limestone outcrops, rises 600 m from the Upper Takaka - Takaka tectonic depression and forms the north-western margin of the Pīkikiruna Range. Hailes Knob (1280 m) is part of the north-east trending Pīkikiruna Range, and is 12 km south of Takaka (Fig. 1). Most of the Pīkikiruna Range drains to the south-east, however the Waitui Stream and Dry Stream drain north-west of Hailes Knob, sometimes disappearing through subterranean marble caverns.

The contact between Hailes Knob Quartzite and Arthur Marble (Grindley 1971) is best exposed in Dry Stream, 1 km north-east of Hailes Knob. The Arthur Marble found there is at least 320 m thick, and is a black to dark-grey, fine-grained, graphitic limestone with exposed inter-bedded muddy and micaceous layers. Graphitic phyllite and schistose bands are common at the top of the formation. Authigenic, euhedral, pyrite crystals are common and interlaminar folding and contorted bedding are usual at several horizons. Several rock outcrops and derived fossiliferous boulders show structural deformation (Cooper & Wright 1972). Fossil crinoid columnals are common throughout but are locally abundant in several stratigraphic levels (Fig. 2).

Cooper (1975) considered the sediments of the north-western area of the South Island formed part of a single Gondwana Palaeozoic segment. This segment included the western, central and eastern depositional belts of north-west Nelson that were direct analogues of the Ballarat and Melbourne Troughs (Brown *et al.* 1968) and interposed Heathcote Axis (Hills & Thomas 1954), of Central Victoria, Australia. On this basis, the Hailes Knob collecting sites are located within the Early Palaeozoic eastern (Melbourne Trough) sediments which were deposited as a continuous Central Victorian and north-west Nelson Belt. These sediments underwent a major diastrophic and metamorphic episode narrowly confined to the Australian Benambran Orogeny of this time (Cooper 1975).

Fossil localities are listed with their New Zealand Fossil Record File numbers in Table 1. All localities from the Upper Takaka district lie within NZMS 260 Sheet N26. Specimens from a fossil locality denoted by a registration number prefixed with "AK", are held at the Auckland Institute and Museum. Those with "E", are held at the University of Auckland Geology Department.

MATERIAL

Previous workers such as Donovan (1984) found it convenient to divide crinoid columnals into two groups, meric (each columnal composed of more than one calcite plate) and holomeric (columnals formed from a single ossicle). A typical columnal is usually thought of as being circular with a circular lumen. Holomeric columnals occur throughout the Ordovician of Europe, however, gaps exist in the stratigraphic range of some genera/morphogenera. New crinoid columnal features appear in the Late Ordovician, coincident with the increase in columnal diversity and numbers. All (but one) known crinoids of the sub-classes Camerata and Inadunata are stem-bearing. No known camerate species has been recorded in which the column is divided into segments by longitudinal sutures; columnals are not composed of tetrameres or pentameres as in some species of the Sub-class Inadunata (Ubaghs 1978).

Any evolutionary study based on fragmentary fossil remains of crinoids is inherently unreliable and cannot demonstrate relationships between disarticulated remnants. Only particularly distinctive columnals are of any practical use in taxonomy since homeomorphs between distantly related taxa are probably common (Hicks 1873). A British Ordovician inadunate example is *Ramseyocrinus cambriensis* which has a column possessing tetrameric



Fig. 2. Photograph of an *in situ* band of fossil crinoid columnals at locality N26/f75 from which specimens of *Archaeocrinus*, *Deocrinus* and *Reteocrinus* were collected.

Table 1. Distribution of Late Ordovician crinoid genera reported from the Arthur Marble at Hailes Knob. A - abundant; C - common; UC - uncommon.

N.Z. Fossil Record No.	N26/939137 N26/f74	N26/942136 N26/f75	N26/945133 N26/f76	N26/947130 N26/f77
INADUNATA				
<i>Aethocrinus</i> sp.	-	-	-	UC
CAMERATA				
<i>Reteocrinus</i> sp.	A	A	A	A
<i>Archaeocrinus</i> sp.	A	A	A	-
<i>Deocrinus</i> sp.	-	C	C	-

columnals proximally and tetragonal holomeric columnals distally. Ubaghs (1978) argues that “although some Camerata have very distinctive columns, most dissociated columnals and pluricolumnals cannot now be attributed certainly to any particular camerate genus. Rarely stated is general agreement that main component parts and ossicles of the body of camerate crinoids are homologous to specified parts and ossicles of other crinoids”.

Using both North American, Russian and British material, Sprinkle (1973), Stukalina (1966) and Donovan (1984) have discussed the early evolution of the pelmatozoan column in ancestral hohlwurzels. The Russian system of columnal morphogeneric nomenclature (Yeltysheva 1956; Stukalina 1966) emphasises the lumen outline e.g. *Pentagonocyclicus* has a circular columnal with a pentagonal lumen. Moore (1939) and Wright (1983), however, give priority to the facet outline. *Cyclopentagonopa* is similarly a circular columnal with a pentagonal lumen and is conspecific with *Pentagonocyclicus*. Pentagonal symmetrical ossicles have been divided into a number of morphogenera by previous authors but the nomenclature does not reflect the true diversity of these columnals (Wright 1983), nor their actual stratigraphic range (Donovan 1984). The New Zealand Late Ordovician fossil crinoids support morphogeneric models, and enough morphological detail is present in the the New Zealand specimens to enable them to be attributed to described genera. Nomenclature in this paper follows Moore (1978) and Ubaghs (1978).

SYSTEMATIC DESCRIPTIONS

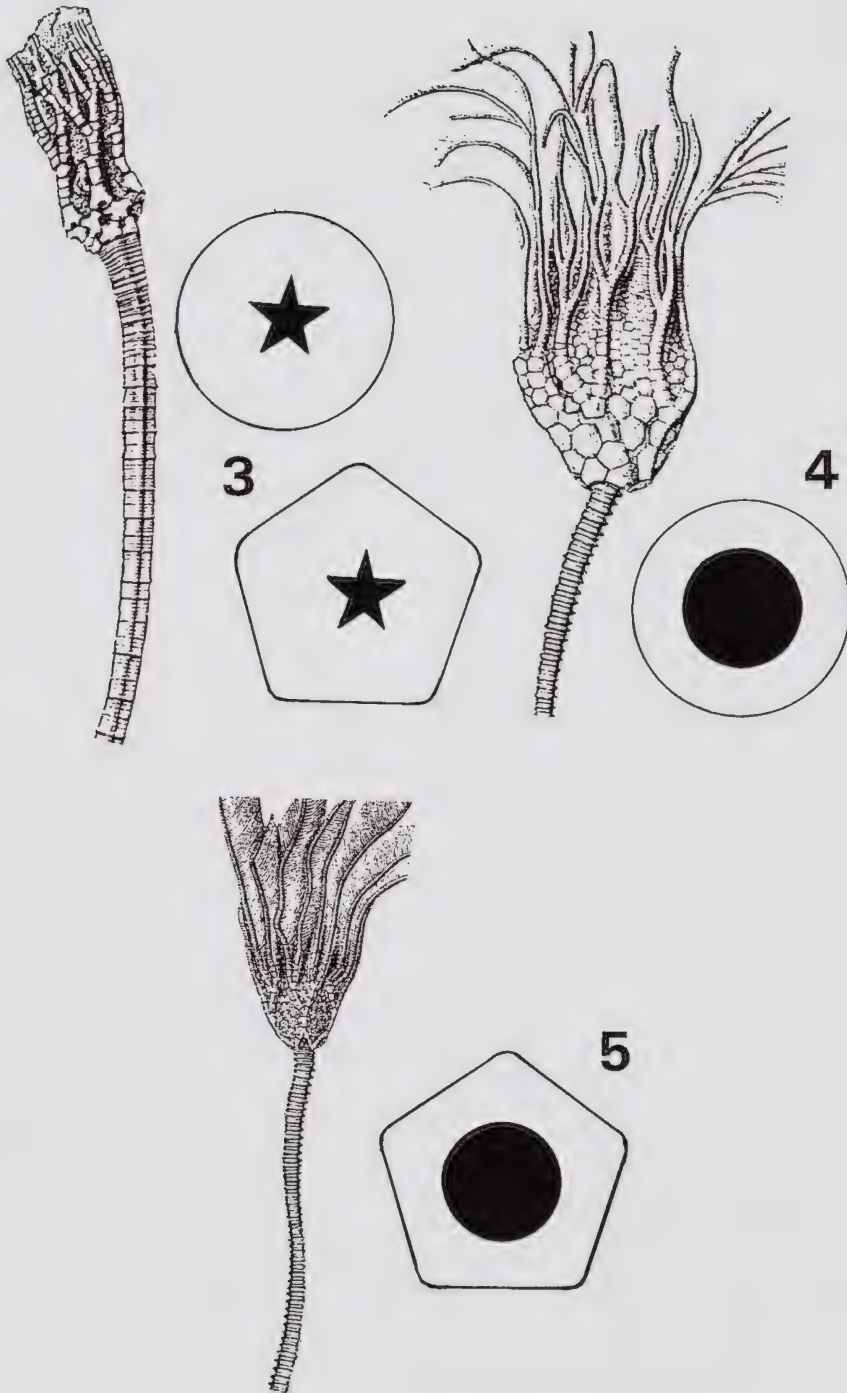
Class	CRINOIDEA Miller, 1821
Subclass	CAMERATA Wachsmuth & Springer, 1885
Order	DIPLOBATHRIDA Moore & Laudon, 1943
Suborder	EUDIPOBATHRINA Ubaghs, 1953
Superfamily	RHODOCRINITACEA Roemer, 1855

Family	RETEOCRINIDAE Wachsmuth & Springer, 1885
Genus	<i>Reteocrinus</i> Billings, 1859
Type species	<i>Reteocrinus stellaris</i> Bigsby, 1868:23 (<i>nomen vanum</i>). Trenton, Canada.
Material:	AK 94172; AK 94173; AK 94174; AK 94175; E 520 (hypotypes).

Description: Column transverse; section passing from pentagonal to round distally; holomeric; columnals possess a pentastellate lumen.

Remarks: *Reteocrinus* is found in the Trenton Limestone (middle Ordovician), Trenton, Ottawa, Canada (type locality), and columnals of the genus are also found in the Ordovician (Caradocian) of Britain. The common occurrence of holomeric columnals with pentastellate lumina in the Ashgill of the South European province is analogous to their abundance at Hailes Knob at the same time (Fig. 3). There appears to be more of the round columnal configuration than the pentagonal and diameter sizes are 1-8 mm. Just as the British specimens may be an indication of the mixing of faunas as the Iapetus Ocean closed, the presence of *Reteocrinus* in Arthur Marble may mean a faunal concentration due to regional shallowing.

Family	ARCHAEOCRINIDAE Moore & Laudon, 1943
Genus	<i>Archaeocrinus</i> Wachsmuth & Springer, 1881
Type species	<i>Glyptocrinus lacunosus</i> Billings, 1857, original description. Trenton, Canada.
Material:	AK 94177; AK 94178; AK 94179; E 521 (hypotypes).



Figs 3-5. Reconstructions and columnal transverse sections of camerate crinoids. 3. *Reteocrinus* sp. (proximal section above, distal section below). 4. *Archaeocrinus* sp. 5. *Deocrinus* sp. in Arthur Marble from localities N26/f74, N26/f75, N26/f76. Reconstructions after Springer (1911b) (3) and Wachsmuth & Springer (1897) (4).

Description: Column round; holomeric; columnals possess a large circular lumen often degenerating distally; distance from axial connective commissure to columnal edge variable, proportional to lumen diameter.

Remarks: Billings (1857) described the columnal as “easily distinguished from that of any other species occurring in the Trenton Limestone” (Middle Ordovician), Trenton, Ottawa, Canada (the type locality). The abundant, round columnals found in the Arthur Marble of Hailes Knob are similar, being mainly small (2-7 mm long; Fig. 4). The large joints of the few pluricolumnals present are proportionally broad while the constrictions between them are wide and deep, being a diagnostic feature of *Archaeocrinus*. Round, holomeric, columnals with large lumens are found in European and North American Ordovician rocks. They have been variously morphogenetically described, and many genera are now synonymised under “*Cyclocyclopa*” (Moore, 1939) and “*Cyclocyclicus*” (Yeltysheva, 1955). Round columnals with large, circular axial canals are known from British, European and North American (Tremadocian-Arenigian) cystoids. Identification of archaeocrinoid forms at the Upper Takaka locality to species level is not possible, however, Hailes Knob columnals show a synostiosial articulation, not the usual holomeric glyptocystitid type of articulation of the cystoids.

Family	ANTHRACOCRINIDAE Strimple & Watkins, 1955
Genus	<i>Deocrinus</i> Hudson, 1907
Type species	<i>Rhodocrinus asperatus</i> Billings, 1859:27, original description. Chazyan, Canada.
Material:	AK 94180; AK 94181; E 522 (hypotypes).

Description: Column pentalobate; holomeric; columnals possess a large, circular lumen; distance from axial connective commissure to columnal edge variable, proportional to lumen diameter.

Remarks: These columnals are common in the Arthur Marble. They are 2-8 mm in diameter. Fusion of the meres has produced a coincident crystallographic orientation and an increase in lumen diameter reminiscent of columnals of the northern European morphogenus *Bystrowicrinus* (Yeltysheva & Stukalina 1963). Retention of a circular lumen in *Deocrinus* (Fig. 5) instead of the stellate configuration developed by *Bystrowicrinus* and *Reteocrinus* is the main difference between the genera. The first appearance of *Deocrinus* columnals in the Middle Ordovician and their later appearance in Arthur Marble at Hailes Knob, suggests that they evolved from a similar ancestor to *Bystrowicrinus*. *Deocrinus* and *Bystrowicrinus* columnals are almost exclusively limited to the North American faunal province until the Ashgillian. The New Zealand specimens appear similar to European and British forms of *Deocrinus*.

Class	CRINOIDEA Millar, 1821
Subclass	INADUNATA Wachsmuth & Springer, 1885
Order	CLADIDA Moore & Laudon, 1943
Suborder	DENDROCRININA Bather, 1899
Superfamily	MASTIGOCRINACEA Jaekel, 1918

Family	AETHOCRINIDAE Ubaghs, 1969
Genus	<i>Aethocrinus</i> Ubaghs, 1969
Type species	<i>Aethocrinus moorei</i> Ubaghs, 1969, monotypy. Europe: Montagne Noire, South France.
Material:	AK 94176; E 523 (hypotypes).

Description: Column pentalobate in transverse section; heteromorphic; column columnals divided by longitudinal sutures into pentameres; large pentagonal axial canal; constant, greatly reduced distance from the axial connective commissure to columnal edge.

Remarks: Columnals identifiable as *Aethocrinus* sp. at the Hailes Knob locality are uncommon. The largest measures 6 mm in diameter but most are 2-5 mm (Fig. 6). The presence of meric sutures in the column of *Aethocrinus* sp. allowed bending and the orientation of aboral calyx crowns when filter-feeding. In a holomeric columnal such as the proxistele of *Megistocrinus reeftonensis* (Lochkovian) of Reefton, New Zealand, flexure was facilitated by crenulated, symplectial articulation (Prokop 1970). Devoid of such symplexy, and because individual columnals were bound together solely by ligaments at the meric sutures, *Aethocrinus* sp. indet. could not have similarly flexed. Flexibility was instead achieved by the inter-ossicle movements of stacked meres, arrayed perpendicular to the longitudinal axis of the stem (Donovan 1990). Only marginal movement was possible between adjacent columnals. *Aethocrinus* was originally described from the Early Ordovician (Tremadocian-Arenigian) of France, but is also known from throughout the Arenigian of Britain and elsewhere.

AGE

Wright (1968) proposed a conodont age of Late Ordovician (Late Caradocian to Ashgillian of the standard British sequence or Bolindian of the Victorian sequence) for the Arthur Marble at Hailes Knob. This age is correlated with the presence of *Deocrinus* sp. columnals which remained almost exclusively limited to the North American faunal province until the Ashgillian. This age is here referred to those marble and limestone lenses of the western exposure of Hailes Knob and derived boulders from that face now located in Dry Stream, Upper Takaka Valley.

FAUNAL ASSOCIATIONS AND PALEOECOLOGY

During the Late Ashgillian, the American and European marine communities appear to have contained few crinoid species, were shallow, epifaunal, often consisting of only two or three genera of crinoids, with perhaps several species of stropheodontid brachiopods (such as the restricted *Hirnantia* community of the Late Ordovician of Britain), with a few corals and bryozoans. The Hailes Knob faunal community contains a similar assemblage and appears to be a southern hemisphere analogue. Crinoids are important indicators of depositional environments (Cain 1968), indicating a shallow water biotope during the Late Ordovician.

In addition to crinoids, the Hailes Knob community contains unidentified sponge and brachiopod impressions, tabulate corals (*Proheliolites goldfussi*, *Plasmaporella* cf. *inflata* and *Paleopora inordinata*) and the rugose coral genus *Strepelasama* (Fig. 7). All are shallow water species. The tabulate and compound rugose corals frequently acted as framework organisms in reefs at this time. Though a shallow sea requirement for the existence of tabulate and rugose corals is unproven (Hill 1956; Hill & Stumm 1956), the known fauna suggests that the Hailes Knob assemblage may have constituted such a reef.

Although large numbers of crinoids remain persistent reef dwellers to this day, they also populate the inter-reef and off-reef environments (Manten 1970). Crinoid mass occurrences are known from present seas. Clark (1915a) described the dredging of tens of thousands of individuals from single localities. Lane (1973) and earlier workers referred to such crinoid colonies, patches and stands, as "gardens" or "meadows".

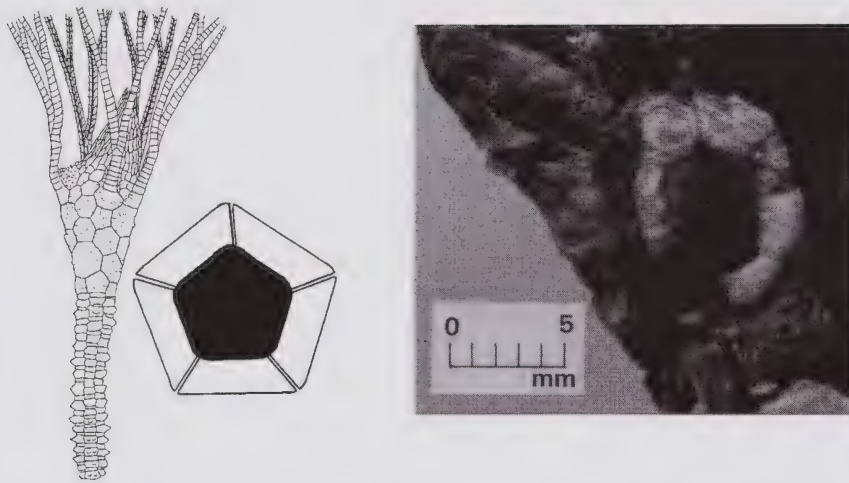


Fig. 6. Reconstruction of *Aethocrinus moorei* after Ubaghs (1969) (left). Photograph (right) and transverse section diagram (centre) of *Aethocrinus* sp. indet. pentameric columnar etched by acetic acid from Arthur Marble, locality N26/f77.

Interpretation of the crinoid record in terms of assemblages or communities is complicated by the rapidity with which crinoid ossicles disarticulate after death (Liddell 1975; Cain 1968). Articulated crinoids from the Silurian starfish bed in the Pentland Hills, England, provide evidence in the form of fine-grained matrix for a quiet-water deposition and rapid burial needed to preserve complicated echinoderms, such as Palaeozoic crinoids, in articulated condition (Brower 1975). Similar lithological conditions are uncommon in New Zealand, hence, the bulk of Palaeozoic crinoid evidence in this country consists of disarticulated columnals or their impressions. Elsewhere, Palaeozoic crinoids are often manifest as “pelmatazoan” or “crinoidal” limestones abundant from Early Cambrian through to Permian times. They particularly occur where terrigenous sedimentation has remained relatively low, such as at the Hailes Knob (eastern Melbourne Trough) segment of the Gondwanan continental sea shelf. Modern crinoid abundance suggests that taxonomically diverse “pelmatazoan” assemblages are more consistent with shelf or upper bathyal depths in the past than with deep-water conditions (Fell 1966a). The distribution of fossil crinoid limestones or “criquinities” as annotated by Laudon (1957), is rarely found in New Zealand but exemplified by the Hailes Knob locality.

The absence of molluscs in the Arthur Marble of Hailes Knob may be an indication that the deposit is not *in situ*. The Hailes Knob assemblage may simply be a chance accumulation of transported pelmatazoan debris. This is supported by the fact that most epifaunal echinoderms, crinoids in particular, do best in an environment of well-oxygenated, subtidal, non-turbid water where current movement is gentle but sufficient to provide an adequate food supply (Booolootian 1966; Macurda & Meyer 1975). The generally long, slender stems of pelmatazoan crinoids are well suited to serve as paleocurrent indicators (Klähn 1929; Wiman 1933; Schwarzacher 1963; Anderson 1968). Pluricolumnals in the Arthur Marble show severe post-mortem movement and are variously paleocurrent orientated. This phenomenon would explain the absence of crinoid cups; fast-flowing currents would have obliterated calices by scattering individual thecae plates. Not so easily explained, however, is the absence of recognisable basal stem holdfast mechanisms.

The strength of these proposed paleocurrents, presumably detritus and plankton-laden, suggests an environmental niche suited to crinoid suspension filter-feeding. The extensive populations of various filter-feeding biota that lived at Hailes Knob suggests the existence of abundant Palaeozoic plankton, of which we know very little.

Conodonts have previously been used to date this open, flat-bottomed benthic marine community where only a small biotic fragment has been preserved (i.e. no nautiloides or graptolites are known from the locality) (Barnes & Fahraeus 1975). East Australian and Hailes Knob Late Ordovician conodonts include the genus *Belodina* which indicates affinities with North American mid-continental faunas (Wright 1968) as do the crinoids described herein. Disarticulated crinoids usually constitute a large proportion of the sediment in North American biotopes and where there was a lack of clastic sediment, wide fossil bands indicate that various sessile species probably covered the sea-floor. This is also a feature of the Hailes Knob locality. Historically, trilobites are extremely rare or absent from this community and this is so at Hailes Knob. It may be due to the substrate being either a hard, biogenic lithoherm or compacted calcareous sands, both being unsuitable for sediment deposit feeders.

DISCUSSION

The articular facet of each of the Ordovician crinoid columnals from Hailes Knob described in this paper, whether Camerata or Inadunata, as in almost all crinoids, have a

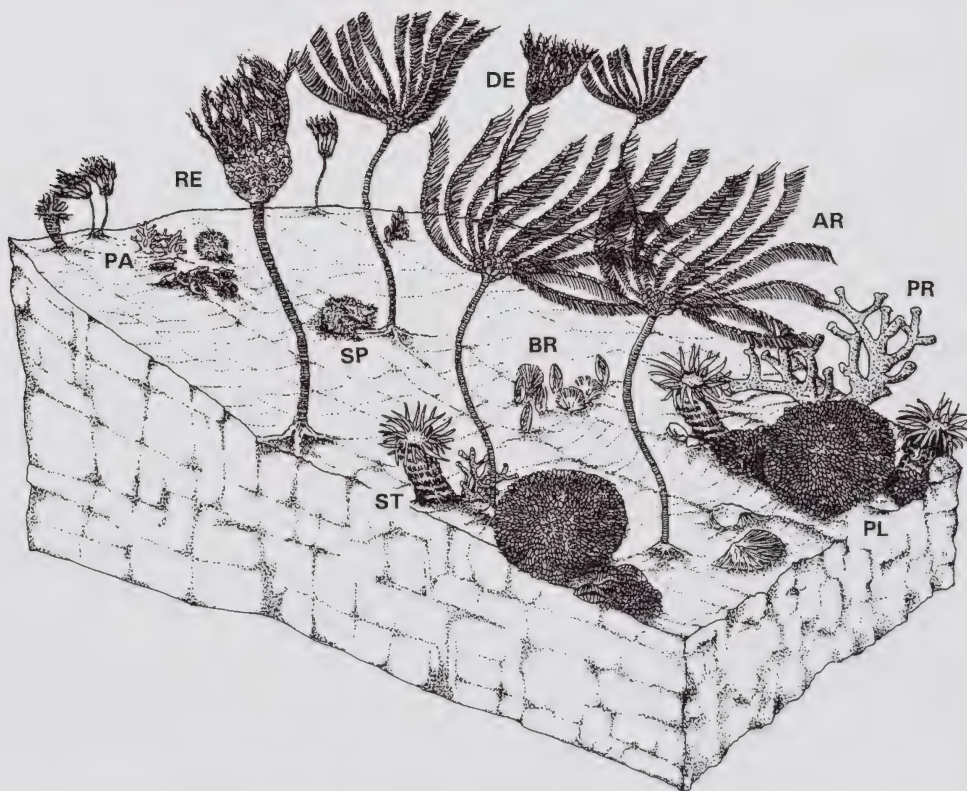


Fig. 7. Schematic drawing of the inner shelf Hailes Knob *in situ* biocarbonate and lithoherm community (10-100 m). No scale implied. AR = *Archaeocrinus* sp. indet.; BR = brachiopods indet.; DE = *Deocrinus* sp. indet.; PA = *Paleopora inordinata*; PL = *Plasmoporella* cf. *inflata*; PR = *Proheliolites goldfussi*; RE = *Reteocrinus* sp. indet.; SP = sponges indet.; ST = *Streptelasma* sp.

characteristic, regularly symmetrical axial canal outline (circular, pentagonal, pentastellate). All the Hailes Knob crinoid columnals possessed large-diameter axial canals that reduced weight and decreased the effective width of each meric suture. The broad cavity created by the axial canal aided flexure and accommodated visceral and perhaps neural organs.

Adaptive trends in the evolution of Palaeozoic crinoids are characterised by an intensified function of movement. This is suggested by the various known skeletal articulation forms of stem ossicles and gradual constriction of the axial canal. This constriction is correlated with the thickening of the stem walls and a proportional increase in the articular facet. Observed morphogenetic changes are useful in Palaeozoic phylogenetic classification (Stukalina 1964, 1966, 1988). The Hailes Knob genera, composed of pentamerous and monolithic columnals, are indicative of the exceptional diversity of adaptive trends that existed world-wide at this time.

The holomeric columnals of the type species *Reteocrinus stellaris* (Biggsby, 1868), *Archaeocrinus lacunosus* (Billings, 1857), and *Deocrinus asperatus* (Billings, 1859) exhibit a planar surface with little or no relief. They are primary circling structures composed of fused meres (Stukalina 1988), having rare synostiosial articulation that barely enabled lateral flexure. The Hailes Knob specimens are obviously primitive in columnar structure and articulation compared with later New Zealand Mesozoic and Cenozoic articulate columnals (Eagle 1993, 1994a). They are typical representatives of crinoid columnals developed from meric columns to form simple, benthic, sessile stems.

All modern brachiopods, crustaceans, molluscs and crinoids have a pelagic larval or veliger stage which drifts with ocean currents for between days and a few months. Late Ordovician species probably went through the same ontogenetic stage, migrating across the oceans of the time (McKerrow & Zeigler 1972). Like New Zealand Late Ordovician shallow marine trilobites and brachiopods, New Zealand crinoids have North American and European

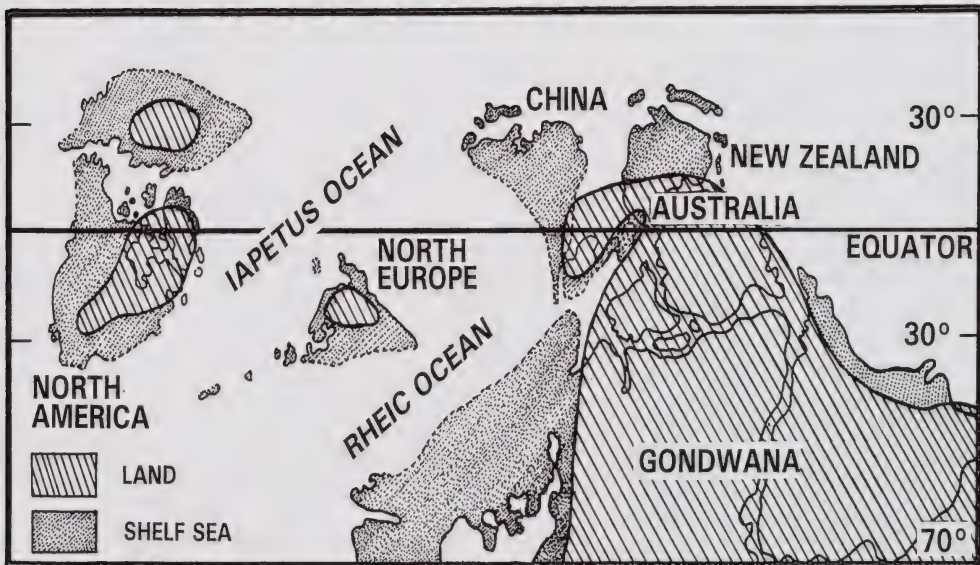


Fig. 8. Mercator projected diagrammatic map of the world during the Late Ordovician illustrating the geographic land and marine relationships between the North American Province, the North European Province, The Iapetus and Rheic Oceans, Gondwana and the Equator (after Cocks & McKerrow 1978).

affinities (Eagle 1994b) (Fig. 8). At present there is no known East Australian - Asian connection as for other groups such as conodonts. It may exist however, disguised in Late Ordovician limestone fragments at such Early Silurian localities as Borenore, New South Wales, where tabulate corals and crinoid columnals have been found (Packham 1969; Laseron 1969). The common occurrence of both pentameric and holomeric crinoid columnals with pentastellate lumina in the Ashgillian of the South European province indicates faunal mixing as the Iapetus Ocean closed; only one *Bystrowicrinus* columnal has been found from the south of the Iapetus suture in pre-Ashgillian rocks (Donovan 1984).

The absence of trimeric, tetrameric or bimeric columnals and the occurrence of only pentameric and holomeric columnals at the Hailes Knob locality may mean that some crinoid groups failed to migrate east or west of the Iapetus and Rheic Oceans at this time. It is suggested that certain crinoids migrated to the Hailes Knob locality between the North American mid sea-shelf westward to the Australasian (Gondwanan) sea-shelf and perhaps also eastward via shallow European seas in the Caradocian. Marked changes have previously been noted in the geographic distribution of some fossil groups in the Mid-Ordovician and this may reflect a climatic change favourable to crinoids at that time (Cocks & Fortney 1982). Climatic or oceanic conditions may have prevented larval distribution either east or west even though there is no paleogeographic evidence of a major land barrier (Cocks & McKerrow 1978). The common premise that the Southern European migration to New Zealand of meric and holomeric columnal species was the only point of faunal origin fails in the light of the proven earlier North American affinities of the Ashgillian sessile crinoids discussed in this paper and of associated species found in the assemblage.

In the Late Ordovician, North American, European and Gondwanan faunal provinces were within 30° N and 30° S latitude, near the equator (Fig. 8). Isolation probably encouraged divergent evolution and the Hailes Knob locality is perhaps indicative of a local Gondwanan shelf marine province that restricted entry to some crinoid faunas and confined others.

Crinoid skeletal material preserved in the New Zealand fossil record from the late Ordovician of Hailes Knob to the present provides an opportunity to study ecologic changes over a long time interval. Because of the great time-span involved, crinoids may provide a reliable biostratigraphic correlation tool in New Zealand.

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